Note: The information presented herein is intended solely to facilitate a working level dialogue between the federal scientific community, and Reclamation water and environmental resource managers, on climate change research needs in support of Western water management. As such, "this information has not been formally disseminated by the Bureau of Reclamation and should not be construed to represent any agency determination or policy," stated in accordance with Information Quality Act (Public Law 106-554), Final Information Quality Bulletin for Peer Review (Office of Management and Budget, December 16, 2004).

CCAWWG Research & Development Scoping and Framing Workshop

Research & Developmentt Roadmap: Managing Western Water as climate Changes

Knowledge Gaps and Initial Research Strategies and Projects

Denver, CO, February 20-21, 2008

For workshop information, see:
http://www.esrl.noaa.gov/psd/workshops/mwwcc/index.html

Day 1 – Wednesday, February 20

11:30 – 1:00: Catered Lunch

12:15-12:30: Opening remarks (Curt Brown)

12:30- 12:45: Reclamation's mission and Overview of R&D Workgroup (Chuck Hennig)

12:45-1:00: Overview of Workshop Handouts (Levi Brekke)

1:00 – 2:10: Panel Discussion - Reclamation Water Operations Managers (Andrea Ray and Curt Brown)

The following panelists provided an overview of their water operations and planning responsibilities, the decisions they have to make, the factors that influence these decisions, and their wish list for climate change related information that would help them make more informed decisions as climate changes. Open discussion was integrated as a part of this panel. In summary, the panelists' information and subsequent discussion served as an "informal gap-assessment" motivated by a water operations perspective, and compliments that "structured gap-assessment" discussion on Day 2. Panelists (UC = Upper Colorado, LC = Lower Colorado, PN = Pacific Northwest, MP = Mid-Pacific, GP = Great Plains, DSP = Dam Safety Program):

UC Region	*Jim Prairie (Region Office, Water Quality Group, works closely with Water Operations Group)*
LC Region	*Terry Fulp (Boulder Canyon Area Office, Area Manager)*
PN Region	*John Roache (Region Office, River and Reservoir Operations Group, Water Operations Team Lead)*
DSP	*Brian Becker (Safety, Security, and Law Enforcement)*

GP Region	*Patrick Erger (Region Office, Hydrology Group, Supervisory Hydrologist)*
MP Region	*Ron Ganzfried (Region Office, Planning Division)*

For pre-workshop information provided by regions and panelists, see "Perspectives from Water Operations Managers on Responsibilities, Challenges, and Needs Related to Climate Change and Western Water" at:
http://www.esrl.noaa.gov/psd/workshops/mwwcc/docs.html

- Upcoming Decisions where climate change information could be relevant
  - (UC) Long-term plan of experimental operations at Glen Canyon.
  - (PN) In State of WA, some irrigation groups are investigating storage proposals to improve water supply reliability.
  - (DSO) Periodic assessments of facility safety and risk lead to decisions to modify/not-modify based on assumed hydrologic loading condition (i.e. extreme meteorological and runoff event possibility). Some ongoing examples: evaluations at Whiskeytown Dam in CA and Glendo Dam in WY, which involve looking at alternatives to permit passing of extreme flood events, like modifying spillways, etc.
  - (GP) Interstate compact on Republican River.
  - (MP) In the CA Central Valley, the federal Central Valley Project (CVP) is managed in coordination with CA's State Water Project (SWP). These systems are aging, system context is changing, and its becoming more difficult to satisfy system demands. Several proposals are being studied that address water supply reliability, environmental benefit (fisheries), etc via reservoir enlargements or construction of new reservoirs.

- Information Wishes – First things that come to mind

  - (MP) Reasonable tools to helps summarize potential climate effects, define range of potential climate scenarios, identify practical/affordable paths/actions.
  - (GP) Precipitation projections in terms of timing (seasonality), regime (snowfall versus rainfall), and location (elevation). Assistance in "proactive" planning (e.g., Water for America initiatives in FY09). Better short-term (seasonal) forecasts of precipitation (snowfall/rainfall in northern part of region; rainfall in southern part of region). Guidance on dealing with water shortages.
  - (DSO) Given a hydrologic load, primary interest is to store or pass load. Secondary interest is water management. Given that interest, do we have indication of how climate change will impact flood frequency curves?
  - (PN) On the operations side, improve water supply forecasting models to account for climate change we've observed. On the planning side, provide guidance on what information is acceptable for use, or what information Reclamation should be using (e.g., in relation to water supply and water/power demand constraints on planning).

- (UC) On the operations side, a "year-2" (13-to-24 month look-ahead) forecast of runoff, conditioned on climate factors (or "2- to 5-year" forecast?). On the planning side, can there be a probability placed on emissions scenarios that frame climate projection simulations?
- (LC) On the operations side, better 1- to 2-year runoff forecasts incorporating climate factors. On the planning side, for defining planning operations criteria, and where risks are explored and rules are sought, need to relate climate scenario ensembles to future risk assessment.

- Questions/Answers and Comments

  - (USACE, Townsley) When does a climate forecast become distinguishable from a weather forecast?
    - (NOAA, Wolter) A two-week horizon is generally the limit for deterministic weather forecasting. Beyond that, expected weather is related more to a climate boundary condition
    - (NOAA, T. Hamill) If you're interested day-to-day information, that's a weather forecast. If you're interested in the future average weather, that's climate. Two-weeks is a hazy intersection. You may be able to give a hint at weather, but you won't be able to precisely define weather details.

  - (USACE, Townsley) What thoughts are being given toward conjunctive use (groundwater / surface water (GW/SW) management) as future management option given projected changes in runoff?
    - (LC) GW/SW management was not considered in a recent study on Shortage Guidelines for the Lower Colorado River Basin states. To-date, GW management has been a secondary consideration in planning given that Reclamation primarily manages SW. Plus Colorado River system has an enormous amount of surface storage.
    - (MP) Some CALFED studies are giving consideration to conjunctive use schemes as future water management options.

  - (MP, Tansey): Effect of climate on sea level change is important in to conveyance of Sacramento Valley CVP/SWP water to service areas in the San Joaquin Valley and CA South Coast, where conveyance must traverse the SF Bay-Delta. Sea level rise relates to Delta water quality issues and Delta island levee integrity.

  - (NOAA, L'Heureux): With respect to risk assessment, how many of you have read the IPCC report and to what degree does the report fall short in providing risk-based information?
    - (LC) The planning environment includes diverse stakeholder views. IPCC offers many climate projections. Reported projections for inflow reductions in the CO river basin range from

0 to 40%. If change in mean is on lower end of that (5-10%), management options exist. If change is on upper end (close to 40%), there's not a lot that can be done.

- (NOAA, Wolter): How would Reclamation use a 5-year climate forecast? And for temperature (T) and precipitation (P), or just P?
  - (UC) Scheduling for Colorado River Storage System is based on a 2-year look-ahead analysis. The first year of that analysis is conditioned on water supply forecast information. The second year is not. UC wish is for forecast information to condition the envelope of supply possibility in the second year. Also, water quality management gets anticipated 2- to 3-years in advance by water customers in lower basin (e.g., for planning salinity treatment on delivered water).

- (NOAA, Webb) For future climate scenarios, is there interest in "which climate models to use" (besides "which emissions scenarios")?
  - (PN) We're interested in both, and we want planning inputs that are stable for a year or so.

- NOAA (Webb): We can assure you that there's no correct climate model. From a downscaling standpoint, NOAA's interested to know about spatial and temporal scales that are desired, for what conditions. Also, caution that precipitation projections from these models are still "a bit wanting."

- (MP, Tansey) Another wish goes beyond projection of longer term climate, and includes associated confidence interval on projections. That would inform contemporary decisions on operating rules that would apply for long term.

- (NOAA, ?) Ensemble averaging of multiple climate models' results usually does better than any single climate model. It is often not clear on which model is best (e.g., one model may do well with climate statistics, but poorly with trend). Also at smaller spatial scales, the signal deteriorates, which is very important for storm-track projections. Whatever we come up with here in terms of precipitation projections probably can only be broad and probabilistic in nature.

- (USACE, Murphy) In the context of Missouri Basin operations, is office is interested in decade-by-decade T and P change, up to 50 years out, reflecting at least change in seasonal T and P norms. In their longer term studies, they need to factor climate into cumulative impacts (along with other issues like sedimentation).

- (NOAA, Soo) For planning with climate or climate change information, what uncertainty information content is useful? How should it be packaged? (potentially by the National Weather Service (NWS))
  - (PN) Currently, PN region uses the NWS "ensemble streamflow prediction" (ESP) hydrologic forecast product, which reflects basin current condition and historical weather during forecast period. The ESP type of information is useful.

- (NOAA, Ralph) We're hearing from two arenas (operations and planning). Estimation of extreme event possibilities (dry to wet) exist at the nexus between these two types of processes. Are there common tools in Reclamation that are used to deal with extreme event information for operations or planning that could be the subject of focus for this dialogue? (In the NOAA world, specific research tasks often have to be tied to existing management tools.)
  - (LC) There are many tools Reclamation uses, varies by system. Hard to boil down to one tool or more limited toolset.
  - (MP) similar comment.
  - (PN, Stark) The Boise Project climate change assessment revealed that "tools" (management options?) for flood control operation didn't fit with climate change scenarios.

2:30 –3:40: Panel Discussion - Reclamation Environmental Compliance Managers (Panel Facilitators: Andrea Ray and Curt Brown)

The following panelists provided an overview of their environmental compliance and restoration responsibilities, the decisions they have to make, the factors that influence these decisions, and their wish list for climate change related information that would help them make more informed decisions as climate changes. Open discussion was integrated as a part of this panel. In summary, the panelists' information and subsequent discussion served as an "informal gap-assessment" motivated by an environmental compliance perspective, and compliments that "structured gap-assessment" discussion on Day 2. Panelists (UC = Upper Colorado, LC = Lower Colorado, PN = Pacific Northwest, MP = Mid-Pacific, GP = Great Plains, OPPS = Office of Program and Policy Services, NEPA = National Environmental Policy Act, ESA = Endangered Species Act):

UC Region	*Nancy Coulam (UC Environmental Compliance Officer)*
MP Region	*Shane Hunt (Natural Resources Specialist, currently split time: ~50% San Joaquin River Restoration effort focused on NEPA/ESA compliance, ~50% CVP Long-Term Operations Criteria And Plan (OCAP) Biological Assessment (BA) for multi-species ESA consultation)*
LC Region	*Cindy Haeft (LC Environmental Compliance Officer)*
PN Region	*Dan Lechefsky (PN Environmental Compliance Officer)*
GP Region	*Gary Davis (Environmental Specialist, Region Office's ESA Coordinator)*
OPPS	*Art Coykendall (policy guidance on env. compliance)*

For pre-workshop information provided by regions and panelists, see "Perspectives from Environmental Compliance Managers on Responsibilities, Challenges, and Needs Related to Climate Change and Western Water" at:
http://www.esrl.noaa.gov/psd/workshops/mwwcc/docs.html

- Upcoming Decisions where climate change information could be relevant
  - (GP) There are several. One example involves replacing a diversion dam on the Yellowstone River to improve pallid sturgeon habitat and sturgeon access to 200 miles of river currently inaccessible. In the design of this diversion, it is important to predict future flows over next 20-60 years so that the capacity of this diversion is maintained, permitting fish passage across the structure.
  - (LC) A couple years ago, a multi-species, multi-agency conservation program was completed, focused on threatened and endangered (T&E) species recovery. Climate change information will be a factor as riparian/habitat areas are developed. For example, how will climate change affect species and habitat for next 50 years?
  - (PN) The Region is currently working with State of WA, USEPA, and USACE in the development of total maximum daily load (TMDL) for temperature on the Columbia River. The amounts to establishing temperature standards related to beneficial uses on the river, including

those involving fisheries, agriculture, etc. Reclamation is interested in how those standards will determine Columbia River system management and Reclamation's storage in Lake Roosevelt behind Grand Coulee Dam. Will infrastructure be required (e.g., temperature control device on release, permitting reservoir depth-choices on release)? It seems like climate change information is necessary to describe future flow possibilities and water temperature possibilities.

- (OPPS) The Region Offices, Area Offices, Research & Development Office, and OPPS have been working together on an options paper (originating at MP Region office) addressing how to potentially incorporate climate change into planning, NEPA, and ESA documents. Completion of that paper has been put on hold for several reasons (e.g., emergence and overlapping concern of the DOI Climate Change Task Force, Law and Policy Subcommittee). OPPS is still trying to help Reclamation offices deal with treatment of climate change in these documents. Litigation is a driver. There's a need for climate change impacts information at the basin-.level and "species" level.
- (MP) The Region is currently consulting on Central Valley Project operations through 2030. There is a need to "forecast" possible flows and water temperatures, and dependent operations through the consultation horizon. Region is required to meet water quality standards in the Delta where sea level is a driver, and sea level rise projections matter in the consultation. Other drivers include climate warming upstream and associated effects on seasonal water availability and cold water resource (i.e. water stored at-depth in upstream reservoirs, and released during Summer-Autumn months to support cold-water habitat required by some fish species).
- (UC) It seems like almost everything the Region is doing in the compliance arena is involving a discussion of climate change. Public concern is a big driver. Region has seen a profound shift over the last 2 to 3 years in the public interest of climate change treatment. Lately, it seems like 10-30% of public comments UC receives on environmental compliance documentation relates to "What are you doing about climate change? How are you considering it?", and they are being received on both shorter-term and longer-term projects alike.

- Information Wishes – First things that come to mind
  - (UC) Two things: (1) Get folks who work with climate proxy records to work with Reclamation hydrologists and encourage them to consider hydrologic variability beyond the historic gage record (e.g., to include proxies from the Halocene period); and, (2) Receive input from NOAA on extreme events, updated web pages summarizing such information that can be referenced for communicating to public forums.
  - (MP) Better projection information on precipitation and runoff implications under climate change, including projections on climate variability aspects like Pacific Decadal Oscillation (PDO), El Niño

Southern Oscillation (ENSO), and their future occurrences with respect to local precipitation patterns and seasonality.

- (OPPS) For planning involving T&E species, need regional to basin-wide projections on how climate will affect federally listed species. Reclamation is forced to face this when we deal with ESA. Environmental compliance programs often look ahead 10 years or more. Climate trend information would also be useful (and attribution of trend effects on species). Habitat effects are often overlooked (e.g., listed plants species, birds). Floods/droughts are important when projecting effects on species.
- (PN) Information needs to start with hydrologic information (e.g., volumes, timing, extreme events, trends), which then needs to be translated into biologic and social effects. Federal agencies (including Reclamation at 30-40M/year, plus amounts from USACE and BPA) are spending lots of money on ESA compliance (i.e. salmon and steelhead restoration. States, tribes, and non-government organizations are also investing in these restoration efforts. Questions are being asked whether current investments might be rendered moot because of climate change, or does climate change render investments even more important given that species will be further climate-stressed in the futures. These questions need answers.
- (LC) How is climate change affecting habitat, vegetation, food chain (insects), and other biological indicators? Insects affect both species habitat and agriculture.
- (GP) In relation to extension of long-term water service contracts, which can have up to 40-year terms, the Region needs to know how to define a "no-action" alternative 40-years into the future (e.g., hydrology under climate change). Region needs basin-scale runoff and water supply information stemming from downscaled climate projections.

- Questions/Answers and Comments

  - (PN) Commenting on map of Columbia River basin (displaying Reclamation, USACE, Canadian, state, and local dams in the basin), its thoroughly plumbed with facilities typically built long ago. Today, a lot of agencies resources are spent on exploring ways to modify operations. Climate change is an extra factor to think about.

  - (NOAA, Webb) NOAA Office of Atmospheric Research recently discussed climate change issues with NOAA Fisheries, which was interested to know error bars associated with fish-temperature tolerances and projected water temperatures.

  - (PN, Stark) Biologists are interested in impact to species on a daily basis. In contrast, many of Reclamation's long-term operations "planning" models have been developed to simulate monthly time-step operations.

- (Reclamation, ?) In relation to need expressed by UC, which NOAA webpages are of interest, and what is meant by extreme?
  - New pages are needed. Summary graphics on past temperature and precipitation across time scales, extreme events, storm discharges, etc.
  - (NOAA, Soo) What is meant by storm discharges?
    - Under Clean Water Act, irrigation activities have largely been exempt. UC is now experiencing situations where municipalities want to discharge stormwater to Reclamation irrigation canals. Region needs to understand storm water event possibilities given such proposals.

- (Reclamation, Parker) Art (OPPS) and Nancy (UC) mentioned that public concerns have been drivers in our environmental compliance treatment of climate change. What's the status of DOI Climate Change Task Force guidelines? Will they help prevent lawsuits?
  - (OPPS) – On the latter question, probably not. But the guide will help illuminate how climate change relates to a given project, and how the information might be factored into the process.

- (USACE, Vaddey) In relation to the question of how accurate does the climate change information have to be, water managers want to "maximize" accuracy. For operations, we deal with seasonal climate and water supply forecast uncertainty. For environmental compliance planning, what's our standard for expected level of "certainty"? How do these thresholds of expected certainty vary between operations and environmental compliance groups?
  - (Coykendall, Reclamation) ESA says "best scientific and commercially available data" should be used. Agencies won't likely set the bar for sufficiency. ESA language is there, subject to interpretation. From a practical standpoint, we want to use the best data available. "How" the data gets used is subject to debate. In some cases, we may have developed "best information" internally, but it hasn't been peer-reviewed, and that can create issues.

- (NOAA, Wolter) NWS web pages exist offering summaries that UC requested. Contact "climate focal points" at NWS or state climatologists.

- (NOAA, Wolter) What's the bottleneck in understanding fisheries response to climate? Is it about projecting climate or understanding fisheries dependence on climate (aquatic conditions, habitat, other species/vegetation, ocean conditions)?
  - (PN) There's a lot of uncertainty on the latter. Questions on potential futility of restoration investments are starting to emerge.

- (MP) Its also about lack of ability to predict ocean conditions and effects on salmon is important.
- (MP, Tansey) In his experience, it would be a mistake to think that we don't understand a lot about the biology. It seems like there's a lot more that we could understand on the relationship between physical processes (temperature, flow hydraulics, sediment transport issues). There are existing simulation models that have been tested in an adaptive framework that show promise. To the extent that we could know climate processes and biological responses, there seems to be a lot of information that we could incorporate into longer-term planning. In MP, he's hearing questions about making restoration project selections among options, and factoring in future climate.

- (NOAA, Ray) What agencies would be involved in translating climate change effects to species and water management needs? (e.g., NOAA Fisheries, U.S. Fish and Wildlife Service agencies (i.e. F&W agencies)?)
  - (OPPS) Management agencies (e.g., Reclamation and USACE) produce biological assessments (BAs), based on input from agency's biologists. F&W agencies produce biological opinions on these BAs, developed by their biologists.
  - (PN) It seems like this question is only starting to get approached. Their region's restoration processes are done collaboratively.

- (USGS, Shafroth) A lot of the biological response information has been developed in the form of general relationships or response curves, driven by physical parameters, flow aspects, etc. Such curves have been developed for a limited set of species and habitats, but techniques do develop such curves do exist.

- (USGS, Shafroth) Question for Art (OPPS), in relation to vegetation and riparian habitats that are important to Reclamation operations, what are some examples?
  - (OPPS) In the Middle Rio Grande, the Southwestern Willow Flycatcher prefers non-native Salt Cedar, which poses some problems. It often nests in riparian habitats associated with reservoirs, and the flooding of those habitats is important for vegetation regeneration, but it can have adverse effects on species habitat.

- (PN, Stillwater) We don't know how to condition our streamflows for climate change when we don't understand future landscape vegetation (and associated evapotranspiration (ET)). We also don't know how to simulate future water diversions when we don't know future water demands.

- (NOAA, Barsugli) What are the perceived needs among panelists for future climate scenarios?
  - (MP) We've been following the state lead.

- (USACE, Townsley) It seems like we need a common vocabulary on how we talk about climate and how that extends to our environmental compliance language.

3:40 – 4:40 *Presentations – Federal Capabilities, Roles, and Interest in Climate Change Related R&D in Support of Western Water Management*

NOAA Climate Science Programs and Capabilities	*Robin Webb*
USGS Water & Biological Science Programs	*Warren Day*

4:40 – 5:00 *Open Discussion and Close-out of Day 1*

Day 2 – Thursday, February 21

8:30-9:30 *National Integrated Drought Information System (NIDIS) - Jim Verdin (USGS) and Robin Webb (NOAA ESRL)*

- *NIDIS Overview and the linkages to climate change R&D needs & opportunities*
- *Overview of planned NIDIS pilots.*
- *Facilitated discussion on the information and capabilities that would be most relevant to Reclamation water and environmental compliance managers related to drought indicators, drought forecasts, and drought impacts.*
- *Next steps*

- Notes on slide show presentation (Verdin)
    - Climate information has been under-utilized in drought management.
    - Drought causes costly losses and information relevant to drought can be integrated to answer questions on factoring drought into operations.
    - Western Governors Association called for federal NIDIS authorization.
    - Coordination of global earth observation systems has enabled progress on NIDIS.
    - It would seem possible tot link concepts applied to drought with those applied to dealing with climate change.

- Questions/Answers and Comments
    - (Reclamation, Brown) During recent drought of record here in CO, water users continue to want to take water this year in anticipation of a better year next year. What are the capacities for better "next year" forecasts?
        - (NOAA, Verdin) This is a need. Many forecasts are available. It is difficult to sift through them all to determine which might apply to a particular location.
        - (NOAA, Webb) NIDIS is working on improving the forecast framework and improve use of existing technology.
        - (NOAA, Verdin) We need to grow a cadre of intermediaries to communicate findings of climatologists to water managers.
        - (NOAA, Webb) USGS also has researchers and staff working on this; it's a common research activity. NIDIS should be aggregating this information. "We know what we don't have – what are we going to get next year?"
    - (Reclamation, Hennig) Links are needed between Reclamation and NIDIS. RDO's technical coordination contacts are Levi Brekke and David Raff. Need to tie NIDIS information back into our climate change work. Avra Morgan is Reclamation's drought program manager in OPPS, and maintaining connection with NIDIS is one of her charges.
        - USGS representatives on NIDIS are Jim Verdin and Harry Lins.

- (NOAA, T. Hamill) Is there a NIDIS focus on natural ecosystems? How is NIDIS funded?
  - (NOAA, Verdin) One of the "customer categories" includes resource managers, so yes indeed. Initial funding is coming from existing activities that already exist, and investing in connections and accessibility. The NIDIS interagency implementation team is supposed to scope needed activities. If an agency cannot support activities, executive committee can investigate alternative funding paths. There is an understanding that agencies are supposed to contribute.
  - (NOAA, Webb) NIDIS agencies need budgets instead of continuing resolutions. Current NIDIS funds are going to initial activities. There is still need for solid foundations on which to go ahead with studies (authorization versus appropriation issues).

- (?) Regarding indicators of hydrologic conditions (e.g., snow-water equivalent (SWE), soil moisture), the U.S. Drought Monitor is a good product to indicate soil conditions. There's a need for information on how soil moisture conditions affect runoff.
  - (NOAA, Verdin) Gridded land surface models have been used in university settings to bridge information gap from climate indication to hydrologic indication. Need efforts in the federal government.

- (?) Aside from NIDIS-specific funding – agencies need to indicate their needs.
  - (NOAA, Webb) There's an emphasis on interagency engagement in the effort, focusing on pilot regions first, getting technology in place and working before expanding.
  - (NOAA, Verdin) Need to identify triggers that different agencies focus on, work backwards to determine how best to approach each individual need, fill gaps.
- (NOAA, Webb) He's heard questions .like why the "teacups" (Reclamation online status diagrams for reservoirs served by regional Hydromet systems (e.g., GP and PN) are not on the NIDIS portal web site, and answers like "everyone does this differently." This raises the thought "ask not what NIDIS can do for you, but what can you do for NIDIS."

(9:45 – 3:45 Potential Research and Applications to Fill Gaps (Three Handouts))

R&D Workgroup Team Members facilitated a discussion designed to provide feedback on Workgroup's draft R&D roadmap documents (i.e. Gap Assessment, Inventory of Ongoing Projects that address Gaps, Collection of Proposed Projects to address Remaining Gaps). An intent was also to generate dialogue between the R&D Workgroup and Reclamation's water and environmental managers that will enable the R&D Workgroup to take the first step toward evolving the roadmap to reflect a comprehensive assessment of the science and information that is necessary to effectively manage Western water as climate changes. This dialogue was framed by a set of three workshop handouts, which can be accessed at:
http://www.esrl.noaa.gov/psd/workshops/mwwcc/docs/Handouts_080219_final.pdf

After this dialogue, workshop participants were invited to share their opinions on how to prioritize gaps outlined in Handout 1. Priority surveys can be accessed at:
http://www.esrl.noaa.gov/psd/workshops/mwwcc/docs/R&DGapPriorities_Managers.pdf and
http://www.esrl.noaa.gov/psd/workshops/mwwcc/docs/R&DGapPriorities_Scientist.pdf

9:45-10:45 Context for Handouts Development (Raff)

Presentation and Group Discussion

- Comparing Day 1 to Day 2
  - Day 1 "gap assessment" is anecdotal based on managers' panels.
  - Day 2 "gap assessment" presentation reflects compartmental approach outlined by a general analytical sequence on relating climate change information to Reclamation's long-term operations planning.

- Climate time-scale represented in Handout 1
  - Focuses on analytical sequences necessary for Reclamation decisions applied to long term time scales.
  - A similar gap assessment is underway targeting gaps related to Reclamation decisions having intra-seasonal and to "2-to-5 year" look-aheads. Today the focus is on longer term decisions.

- Development of Handout 1 – Decisions Inventory (step 1 of 3)
  - The Handout 1 gap assessment was initially framed by a survey of Reclamation decision types having longer-term application horizons, and the different office types where they occur. Four decision-types are highlighted:
  - NEPA Documentation (MP, Ganzfried)
    - Process involves application of the scientific method, evaluating proposed "actions" (and "action-alternatives") under existing and future conditions (e.g., actions being proposed re-operation of existing facilities or proposed new facilities or programs).

- Need to identify the plan that is the best in terms of avoiding or mitigating adverse effects and in terms of reasonably optimizing economic benefits and non-monetary impacts. In other words, identify least environmentally damaging practicable alternative.
- Process must comply with existing laws (ESA, Clean Water Act, NEPA), principles and guidelines.
- There are opportunities to bracket future effects, including potential future climates.
- Look-ahead horizon can be multi-decadal.

- ESA Consultations (PN, Stark)
  - *See Day 1 description (Environmental Compliance Mngrs. Panel)*
  - PN recently completed a 30-year ESA consultation on Snake River. There was a disconnect between information hydrologists produced (monthly system operations) and what biologists needed (daily). This will be a challenge for climate change analysis.
  - For the future, as we learn more about both species and climate change, temperature will play a larger role in analyses. What might happen to temperature is as important as flows. PN species status assessments are currently focused on streamflow.
  - As ESA moves into recovery instead of just impacts, the standard for science and hydrology will become more important
  - Water supply reliability (level of amount and assurance) has become a critical factor in biological assessments/opinions. Climate predictions will factor into these analyses
  - Look-ahead horizon varies with the species and complexity of the system – 30 year BO, 10 year BO is more common.
  - Question – fish die off in Yellowstone this summer blamed on warm temperatures – how can we say whether these incidents are climate change-related or operational or other?
  - Need more data on cause/effect of temperature on habitat and population – we don't necessarily have enough data now – very intense/expensive prospect to study these issues. Reclamation is making huge investments in gathering data – 100's of 1000's of $$.
- Dam Safety Comprehensive Facility Review and Issue Evaluations (TSC, Raff)
  - Hydrologic Hazard Analysis
  - If you have to mitigate for an unacceptable risk – changes required to structure or management – multi-decadal effects of decisions on mitigation
- Flood Control Rule Curves (RC) and Updates (USACE, Townsley)
  - RC development for Reclamation facilities are set up in a consultation between the two agencies.
  - RC describes over time the allowable storage in a reservoir.
  - RC development focuses on a look-back on historical reservoir – how deep to make the pool for a foreseeable flood season

- Is risk of flood reduced or increased by climate change?
- Historically has been a lookback process – climate change presents a challenge in re-examining RC's – processes must be re-visited.
- Folsom now going through getting an emergency spillway. NOAA/NWS Advanced Hydrologic Prediction System (AHPS) is being used to help develop new rule curve. Looking at forecasting information from AHPS and construct new RC to make a flood "not worse than it would have been without the dam".
- Definitely need climate information to feed into this process.
- Time frame for re-visiting rule curves is typically 10 or 15 years – many dams haven't been re-visited in many decades. Funding is a question. Time and staff is a challenge.

- Development of Handout 1 – Recognizing potential analytical approaches to incorporating climate change into planning studies (step 2 of 3)
  - Decisions types just discussed are common in that they deal with multi-decadal issues, and are potentially influenced by climate change.
  - Scoping Questions - How and whether climate change "should" be used in a planning process? A conceptual "NEPA" decision-tree was presented, adapted from a concept originally from Bill Rohwer (MP). Several discussion topics followed:
    - "climate change-relevant time scale" – this is an important concept in our consideration of whether to incorporate CC in analysis.
    - Questions were discussed re: the validity of using a limited hydrologic period of record for analysis (e.g., in terms of the representing potential dry periods, how these records might be adapted to reflect climate change, whether historical records serving as proxies for streamflow variability should be "conditioned" to reflect observed climate change (e.g., detrended)).
    - (USACE, Wortman) On question 3 of flow chart – how does authority of source of climate change information come into play, and the reference period upon which that climate change information is based? Different choices among the climate change information that is available can have an impact on your study outcomes. This gets to Dave's point of "do you trust the information".
    - (LC, Fulp) The chart illustrates where we are today – not perhaps where we'll be in 10 years. We've done virtually nothing to date in incorporating this kind of information. This is a new process. If you get to question 5 or 6, you have to ask what you've done in the past. It is hard to leap immediately to Option 5. You have to move stakeholder community with you through the process of using climate projections versus existing historical data.
    - (TSC, Brekke) On question 5, it is important to distinguish the questions of whether "comparison of the alternatives" is sensitive to the climate assumption (e.g., *differences* between alterantive-

specific benefits and effects computed relative to no-action) as opposed to "is a specific alternative's depiction" sensitive to the climate assumption.
    - (NOAA, Webb) Stakeholders understand that "past performance is no guarantee of future performance". Many stakeholders are ready to make the leap.
    - (LC, Fulp) Need to characterize the risk appropriately – if scenario uncertainty leads to broad outcome uncertainty, then the information may not be very useful to stakeholders.
    - (USACE, Townsley) Many people ignore the "disclaimer." We are responsible for making sure people are aware of the uncertainties and bringing information to stakeholders efficiently.
    - (USACE, Wortman) To reinforce Stu's point, multiple discussions of risk and uncertainty with the public often get misunderstood – people want to know what is going to happen, not uncertainty about outcomes.
    - (PN, Stillwater) Uncertainty is a big issue. We might consider giving stakeholders low, medium, and high estimates of climate change in planning analyses. But just adding in 3 climate change scenarios geometrically increases amount of planning information.

- Development of Handout 1 – General Analytical Sequence for Quantitative Approaches for incorporating climate change into planning studies (step 3 of 3).
    - A generalized analytical sequence is presented, and serves as an outline for discussion on analytical elements and gaps to follow.
    - Analytical sequence features elements included in previous studies exploring climate change implications for water resources management.
    - Several discussion items were raised:
        - (MP, Ganzfried) Where does the analytical sequence address the issue of changes that we need to make to our projects to avoid or counteract adverse effects of climate change?
        - (TSC, Brekke) That's an adaptation question that gets raised after applying this analytical sequence to assess potential for adverse effects.

10:45-2:30 Handout 1 - Overview, Discussion, and Prioritization of Science, Data, and Information Gaps (Brekke)

Presentation and Group Discussion

- Overview of Session
    - Before lunch, an overview was presented on gaps by analytical element.
    - After lunch, the analytical sequence and elements were revisited, with discussion focused on the gaps identified, gaps not identified, and thoughts on priorities.

- Participants were invited to make gap-prioritization notes on two tear-sheets at end of the Handouts – tailored for either management or science perspectives.

- Analytical Sequence - Element #1: Summarize Literature
  - Gap 1.1: Clearinghouse, Scientific Literature
    - (NOAA, Hoerling) Working groups have already done some of this. Is there need to assign people to do a synthesis paper?
    - (NOAA, Webb) Synthesis and assessments under way (CCSP). Marty and Brad are working on two specific examples of these.
    - (?) Distinguish boilerplate summaries accessible to the public.
    - (Reclamation, Hennig) Is there a way through CCAWWG to synthesize or filter information that is available? Can we provide a critique of climate change information in the news, perhaps for science agency level, management agency level?
    - (USACE, Townsley) What is the sense on how a clearinghouse should be hosted? Each agency already has some repository of information – how do other agencies get access, how do we share information?
    - Is there an interest in information on verifying applicability of data or tools?
  - Gap 1.2: Region-specific Literature Summaries
    - Region-specific focus – how can this be generalized so it's applicable to other agencies with different regions/divisions?
    - How often would the information be updated?
    - How much literature is actually needed?
    - The gap that exists is between the climate science that does exist and the implementation of it. Literature is not necessarily the way to bridge that gap – case studies and examples might be a better way to address the gap.
      - (Brekke) This comment gets to the question of literature review scope. If we review a broad enough sweep of articles, can that provide the kind of information that environmental compliance people need to do their work?
    - Keep information sector-relevant – case-histories of how information is used in making decisions. This is more valuable than a repository of information.
    - (USFS, ?) They're often called on to synthesize information in context for activities. They can see starting out with regional boilerplate syntheses and then getting more specific information included as available.
    - (NOAA, Hoerling) NOAA has regional integrated science areas (RISA's) – they can be a resource in this effort.

- Analytical Sequence - Element #2: Obtain Climate Projections Data

- Gap 2.1: Downscaled data at finer resolutions (space and/or time) and different variables
  - (NOAA, Webb) re: temporal aspects of downscaled data. There's an "industry" of projections downscaling. We don't want to "do the wrong thing more precisely". Be careful of what credibility we lend to this data.
  - (Brekke) What is a credible downscaling resolution? Where should this information come from and how will water managers know?
  - (USACE, Townsley) His planners would want 15 minute information at NWSRFS watershed level. But what is feasible? Monthly time steps don't work for flood operations. Daily can, hourly is better.
  - (Reclamation, Brown) Tradeoff - reliability versus resolution.
- Gap 2.2: Downscaled data that isn't based on "stationarity" (e.g., potentially revealed using regional climate models)
  - On the reliance of statistical techniques for downscaling – the observed data underlying the techniques are important. How good are these data on which to base the techniques?
- *Gap 2.3: Evaluation and verification of downscaled information*
  - New Gap: Evaluation and verification of downscaled information is a gap in and of itself
  - (MP, Tansey) Is it possible to associate with downscaled climate information something that gives us a measure of the reliability with the downscaled data? Precipitation and temperature information is what he expects. He's interested also in vegetation and water use, so it would be good to have solar radiation, relative humidity, wind speed etc… - what is available? How reliable is it?
  - (NOAA, Barsugli) We trust temperature projections more than precipitatin projections. Reliability of downscaled data depends on the area and specific downscaling techniques.
  - (NOAA, Hoerling) It's impossible to verify the climate model data, so it's hard to determine measures of reliability. Reliability might have to be qualitative instead of quantitative – more based on understanding of the physics than on calibration.
- Other Discussion
  - (PN, Stark) What are we doing to increase reliability of precipitation data?
  - (NOAA, Udall) People are not fully informed of the utility of these models – how good are they? There are about 60 people working on climate models right now in the US. We need more people working on this question. It seems that can we put more effort into this.
  - (USACE, Vaddey) Rather than access to downscaled data, he'd like to have a tool that performs the downscaling on the original climate model output. Motive is to make the data immune to being used improperly by understanding the development process.

Establish a framework or a set of tools that will let people make decisions on their own.
        - (USGS, Hay) Many of the hydrologic models rely on spreadsheet data management, which are difficult to link to climate data data sets (format issues). Need a tool that polls climate data and puts it in a format useable by the (hydrologic) models people have. Some models might have to be re-developed to be compatible with spatially gridded climate data.
        - (USACE, Wortman) Models based on point data might not fit with spatially gridded data.

- Analytical Sequence - Element #3: Translate Climate Projection Data into Planning Scenarios
    - Gap 3.1: Basis for Weighting Climate Projections
        - Originally labeled "Basis for weighting Emissions Paths" in Handout 1
        - Assigning probability to the future condition is difficult – you'd probably be wrong – more appropriate to look at a range of possible futures.
        - Rather than weighting possible futures, look at operations projections.
        - But looking at the emissions paths – can have wide swings in likely outcomes. This means you have to look at the range of operational implications.
        - Rather than weighting projections, an approach might involve bracketing future scenarios. This is being explored in some studies – no standard practice right now.
        - On weighting projections – right now weather forecasting is a human/machine mix – needs an analyst who is familiar with each model and what they're good at. There's an analog with the climate models. Maybe one IPCC model is better than another for a particular application. Some IPCC model results are already out of range in terms of validity.
    - Gap 3.2: How to jointly consider paleoclimate, near-term climate variability, and projected climate
        - (NOAA, Hoerling) re: relevance of climate change information -- consider the signal of the response. Suppose a climate signal is derived by grouping all climate models' projections together – bad and good. Ensemble mean impact might be 5% - 10%, but how does that compare to the variability of the historical record? This can determine whether or not climate change is likely to affect this area.
    - Gap 3.3: How to assess extreme meteorological possibilities in a changing climate
        - On extreme events, there's expectation for stronger storms given more atmospheric water.

        - Primary regulatory agencies rely on probable maximum precipitation (PMP) estimates to drive probable maximum runoff estimates and associated design considerations.
        - (Raff) There are no longer efforts focused on updating these (PMP) estimates. Definitely a gap.

- Analytical Sequence - Element #3: Assess Natural Systems Response
    - Gap 4.1: Climate impact on groundwater and interaction with surface water
        - (MP, Tansey) If we had climate projections, we could look at the interactions between groundwater (GW) and surface water (SW) – we have these tools – why is this considered a gap? For example, (an MP SW management model, CALSIM III) should allow us to represent interactions between GW and SW. The tool is there, but we just don't have future projections of climatic data that could enable us to look at recharge differently.
        - (TSC, Brekke) Elaborating on Mike's comment, in the California Central valley, efforts have been made to incorporate GW response functions into a SW operations-decision model (CALSIM III). What is the sufficiency of these tools to represent the GW-SW interactions affected by climate change scenarios?
        - (USGS, Bruce) New packages are continually being developed to implement new methods of representing GW recharge. Focus might be to understand the episodic nature of recharge. Air temperature, evapotranspiration, latitude, etc., are all conditions that affect recharge. One question is residence time of groundwater before reaching streams. New modeling packages like GS_FLOW should provide new capabilities.
        - (USGS, Manning) As you move outward in time to larger time scales, GW becomes more important. It's a storage vessel that retains memory of multiple years' conditions, and it's a base flow source. Including these aspects in water supply models is a critical piece. There's a data gap at the high end of the system in the high mountains in predicting headwaters processes.
        - (TSC, Brekke) This last point highlights that most of our GW model applications focus more on lower elevation (valley) areas.
        - (NOAA, Webb) We have gaps in monitoring, process understanding, and modeling representation – technology is improving.
        - (Reclamation, Hennig) We built a lot of surface storage last century. This century will probably see use of groundwater storage playing a bigger role.
        - (USGS, Markstrom) On coupling GW models with SW models, challenges include scale and resolution of the different systems, fundamental differences in responses. A SW drought and a GW drought are not necessarily concurrent.

- Gap 4.2: Climate impact on land cover and ecosystems
  - This gap relates to sedimentation impacts to reservoir storage.
  - (MP, Tansey) MP simulates water temperature below reservoirs on short time scales. Daily maximum and minimum temperature conditions are required. Are these conditions available from climate projections?
  - (USFS, Hubbard) Changes in the tree line affects snow interception, watershed demand. They're trying to collect data on ecosystems response to climate change, affects on water use, understory changes on interception…
  - (USFWS, Anderson) On ecosystem changes, changes of interest include seasonal wetlands' presense and extent, air temperature, timing of seasons. These changes affect bird migration, food network, snow zone, high elevation ecosystems.
  - (TSC, Brekke) On translating this into a gap – do we have sufficient knowledge to estimate an ecosystem response given a climate scenario?
  - (USFWS, Anderson) Confidence in temperature projections is an issue – will trends continue?
- Gap 4.3: How to assess flood control rule requirements in a changing climate
- Gap 4.4: How to assess extreme hydrologic possibilities related to dam safety in a changing climate
- Gap 4.5: Guidance on runoff analysis dependence on method/tool; and method/tool preference

- Analytical Sequence - Element #5: Assess Social Systems Responses
  - Gap 5.1: How to project social responses to that constrain operations (e.g., water demands, flood protection, environmental values)
    - Vegetation response to climate change is a natural response, but "district-level" irrigation demand is influenced by social factors
    - (USGS, Hay) How do we also include land use change (e.g., urbanization)? Usually this information is provided by external parties. Sources vary from region to region.
    - This is a social science gap. Water use and distribution at its core is a political and social process – driven by values – formalized in a series of rules, regulations, and policies. Values may change and rules may change in response to this.
  - Gap 5.2: Crop water demand response to climate and atmospheric carbon dioxide changes
    - Plant evapotranspiration response to climate change depends temperature and carbon dioxide (CO2) change (e.g., as CO2 in atmosphere increases, water use efficiency may increase). What do we know about ET responses to climate change?
  - General Discussion

        - Overarching themes and questions – some can be addressed by existing information and work.
        - Some of the questions are very site specific – physical and social information both play a role in the answers. People need to specify what questions they need answers to – are they general or site-specific.

- Analytical Sequence - Element #6: Assess Operations and Dependent Resources Response
    - Gap 6.1: Experience conducting policy-search studies (e.g., "crystal-ball" operator, optimization)
        - We have our existing planning tools that simulate our operations with the policies we currently have (e.g., regulations, institutions). Do we have screening tools in place that permit policy search studies? Do we need these?
        - (PN, Stillwater) We do have tools and skills, although money is always a problem.
        - (USACE, Wortman) USACE has not made much effort to develop tools of this nature. Momentum is slow. Its hard to explore policy changes.
    - Gap 6.2: How to blend "static" and "crystal-ball" operator depictions into realistic portrayal of operations unfolding under climate change
    - Gap 6.3: How to analyze operations impacts on climate
        - How do we estimate the carbon footprint of our operations?

- Analytical Sequence - Element #7: Assess and Characterize Uncertainties
    - Gap 7.1: How to assess and characterize uncertainties by element
        - (NOAA, Webb) Concerned that we scare people by saying "uncertainty". We do risk management today. Let's rephrase uncertainty as "how is climate modulating our understanding of the envelope of risk that we're already studying"?
        - Even without climate change, there is already some uncertainty. Climate change information changes the risk and also the envelope of risk.
        - (NOAA, Hoerling) How do we know how well clients have articulated how sensitive their systems are to what aspects that may react to climate change? Is a system more sensitive to an extreme event, or to a shifted runoff distribution? Each planning study we do has to answer this question in a unique way.
        - (Reclamation, Hennig) Reclamation's Dam Safety Program uses a risk framework – a range of events – to explore how a structure might react to a range of events. Just going through the mechanics allows the technical team to break each event down into its technical parts. Perhaps use the work we've already done in characterizing risk and uncertainty to help in framing what's associated with climate change study results

  - Gap 7.2: How to how uncertainties interrelate and/or compound across elements

- Analytical Sequence - Element #8: Communicate Uncertainties and Incorporate into Decision-Making
  - Gap 8.1: Experience communicating uncertainties associated with climate change and its relation to Reclamation planning processes
    - Ultimately decision makers need very simple summaries of the problem and solutions.
    - (GP, Erger) Yes – managers don't have time to deal with complexities – need to simply code or otherwise indicate risk

2:45-3:15 Handout 2 – Review and Discussion of Ongoing Projects to Address Gaps (Raff)

- Presentation
  - Handout has one-page descriptions for each project.
  - Presentation highlighted those associated with the CCAWWG.
  - By "ongoing," it is meant that budget has been allocated for this work and that work is scheduled and/or under way.

3:15-3:45 Handout 3 – Review and Discussion of Proposed Additional R&D Projects to Address Gaps (Raff)

- Presentation
  - Handout has one-page descriptions for each project.
  - Each proposed project would fill an identified gap if funded and completed.
- Group Discussion
  - Question on project III-4 ("Climate change, reservoir management, and the differential success of invasive and native riparian plants") Will the study extend to the species that use habitat in vegetation to be studied? Or is species impact considered an extended impact of the principle focus of the study?
    - Reservoir margin habitats would be studied in III-11 ("Predicting Colonization of Reservoir Margins by Invasive Plants"). Intent isn't to specifically address habitat.
  - Re: inventory of long term riparian monitoring sites on regulated rivers with references on unregulated rivers - Changes in how regulated rivers are regulated may mask the impacts of climate change. What are climate change impacts, independent of adaptation of operations and river management?
  - (PN, Stark) – Cottonwood regeneration is an issue that the PN needs to deal with in some areas – potential area for climate change impact – this might be addressed in the proposed activities.

3:45 – 4:15 Open Discussion

- (USACE, Vaddey) re: training program for hydraulic engineers in how to work with climate data sets and models – if tools are developed it would help people to be more familiar with the sources of the data.
    - (Reclamation, Stillwater) It would be good to have training on concepts of climate change too, not just on tools.
- (Reclamation, Tansey) MP started several projects in the last several years without foreseeing climate change element but could easily be adapted to incorporating it. One effort has involved collaboration with the TSC River Hydraulics and Sedimentation Group, focused on channel meander and point bar formation resulting from reservoir releases coupled with seasonal runoff, riparian vegetation establishment and survival. They're also trying to advance understanding of interactions between hydrologic processes and vegetation – dynamically coupled plant growth model using solar radiation and relative humidity and vadose zone representation with surface water representation. A related issue is how climate change would affect establishment of riparian vegetation.
- (?) What is the process to get current on information about proposal idea feedback and funding potential?
    - Contact Dave or Levi. Its hoped that the "Handouts" document will grow and address potentially additional gaps as they're identified.
- (Reclamation, Hennig) We'll be looking to set up capabilities of submitting proposals over the web. Current web site is on the top of the handouts.

3:45 – 4:30 Training, Knowledge Transfer, Outreach, and Communication

- Discussions facilitated by Andrea Ray (NOAA)
    - (?) Re: "Climate Change 101" – (Ray) Would training would be a good idea for many managers and technical people, perhaps to provide a more formal opportunity, recognized across agencies?
        - (?) DOI Climate Change Task Force recognizes need for Climate Change 101. It's a widely accepted national need. It might be done on a regional basis.
        - (NOAA, Udall) Climate science teacher has a series of 6 UTube videos that we should all watch
    - Re: Science integration and ushering information from research realm to application – (Ray) How can NOAA-RISAs help? (e.g., Climate Assessment of the Southwest (CLIMAS), described by Dan Ferguson) How can state water institutes help? (e.g., Arizona Water Institute, Water Resources Research Center)
    - Re: Communication – (Ray) What are the needs of Reclamation and other agencies when talking with their stakeholders?
        - (LC, Fulp) Re: Outreach and Communication, common sense dictates what to do. Come early and be consistent. Involve stakeholders from the beginning. Speak from the heart –

stakeholders can sense insincerity. Outreach is costly in both time and energy/psyche, and this should be understood when planning outreach and communication efforts. When LC started the planning process involving proposed coordinated operations for Lakes Powell/Mead and shortage guidelines for lower basin shortages, from the onset LC/UC explained to participants that they'd do something other than look at the 100 year record. LC/UC had already prepared a plan of action before this though, and had a solid plan to explain. LC/UC anticipated skepticism, but they were able to bring stakeholders along through the process.

- (USGS, Burkardt) Think carefully about who your stakeholders are, which can depend on how contentious and broad your problem is. Better to have too many stakeholders involved than too few. Understand what their interests are and what power they have. This makes a difference. Sometimes you find support in unlikely corridors. Spend time working on stakeholder analysis.

- Re: Web Resources for learning about climate
  - www.nwrfc.noaa.gov/westernwater
  - regional climate centers www.wrcc.dri.edu
  - NOAA-RISA websites (CLIMAS, CIG, CAP, WWA)
- Re: Credibility and Value of Information – (Ray) The challenge is that science is (unlike water management) is ego-driven. There are inclinations to have press releases on new research products or comment on others'. Pre-publication press releases of new papers are common. It's a challenge to provide information that should be used in a measured fashion and would support decisions. Is a panel of experts needed to advise the water management community on what information to use? The water management community is probably not getting this guidance from the IPCC.
  - (USGS, J. Hamill) In the Glen Canyon Adaptive Management Program, all of their work is reviewed by an independent group, which helps with questioning stakeholders. They look at work plans and published work.
  - (NOAA-RISA WWA, Udall) There is a hunger out there for more information and everyone gets interested in good analysis/science. There are challenges and the sense is that people are ready to address them using new information. This introduces cost concerns – people need to think they're getting something for the money they're spending.
  - (NOAA, Ralph) Credibility and trust are really what's necessary to make change. Science plays a role in reducing uncertainty and risk. But there is a need to ensure that the climate scenarios encompass full range of possibilities. If you use one weather model run 20 times you get a range of outputs, but that's not enough because they don't include the full range of possibilities. Multiple model ensembles provide a broader range of possible

outcomes. Model ensembles can predict outcomes that are not comfortable, but if they're part of the ensemble it lends credibility. An example is how the Arctic Ocean ice extent during Summer is diminishing more quickly than expected; no model predicted it would decrease as quickly as it had. Just because something seems extreme doesn't mean it can't happen.
    - (USGS, ?) Remember roles – who are you providing information to – make sure expectations are clear.

4:30 – 4:45 Close-out and Next Steps

- (Reclamation, Hennig)
    - Workshop Summary:
        - Barb Deloise(?) has created web site for CCAWWG and this workshop (http://www.esrl.noaa.gov/psd/workshops/mwwcc/index.html).
        - We will get a draft out soon of notes on the meeting
        - Regarding the two gap assessments (Day 1 and Day 2), the Day 1 gaps discussion (i.e. "wishes" from the Regions' water operations and environmental compliance managers) will compared against the gaps discussed on Day 2 and integrated into the research roadmap as needed.
        - Prioritization sheets – results will also be put on the web
    - Next steps
        - See handout on "What's next…" featuring q&a's on what we anticipate.
        - Making it up as we go – adaptive management.
        - CCAWWG sponsors have been meeting regularly – this will continue.
        - This is the first of what is hoped to be a series of meetings.
        - Will be reaching out to state and local water agencies to keep them in the loop. Unique niche in western water management.
    - Additional Feedback?
        - Participants thinking of additional research problems or gaps are invited to submit them to CCAWWG group – they'll get added to roadmap planning.
        - If you want to Collaborate – let us know. We want to collaborate too.
        - Appreciate all participants and want to continue the dialog – let us know what is helpful.
- (USGS, Day)
    - Thanks to everyone for participating, to Levi and Dave for their efforts, to Chuck and Curt for launching the effort.
    - Lots of moving wheels and gears in the USGS – need to keep the right people on the process.
- (NOAA, Webb)

  - Thanks to Andrea and Klaus, and everyone who came.
  - Two mandates for follow-up:
    - (1) front range workshops on what we can do locally,
    - (2) identify ways to do discretionary investments and working things into their budget
  - When CCAWWG (?) comes up with key findings and gaps, having interagency agreement on focus will help.
- (Reclamation, Brown)
  - Thanks to all the Reclamation people who came from afar, partners in NOAA and USGS – glad others think this is important.
  - Reclamation will continue to steer resources towards this challenge and will leverage the heck out of it.